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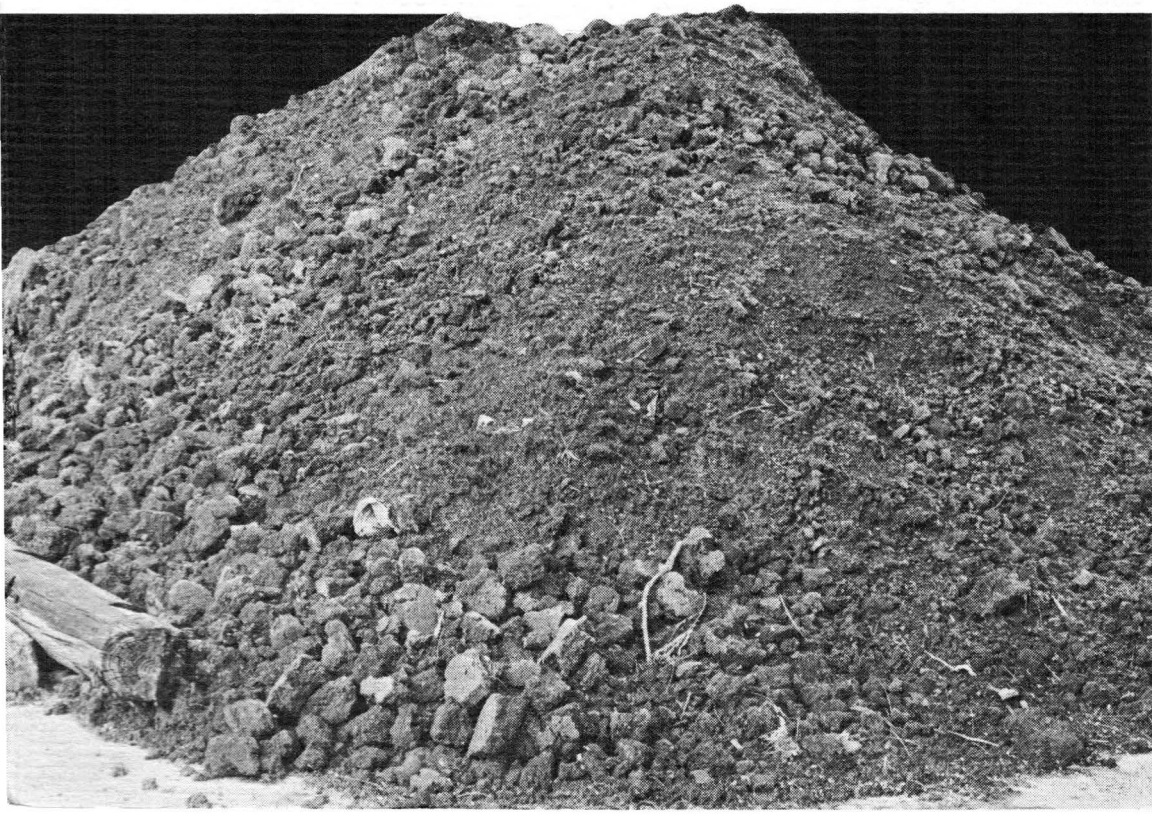
Soil Organic Matter

WADE W. McCALL
Soil Management Specialist



SOIL ORGANIC MATTER

By Wade W. McCall
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Soil is a mixture of organic matter and minerals. Organic matter is very complex and influences the physical and chemical properties of the soil far out of proportion to the amount present in the soil. The greatest problem for the grower is maintenance of the material at economic levels in the soil.

Forms of Organic Matter in the Soil

Four stages or forms of organic matter in the soil are: fresh, partially decomposed, microbiological, and humus. The fresh or undecomposed material consists of the remains of plants and animals. These may be added to the soil or grow in the soil, such as plant roots. This material begins to decompose as soon as it is added to the soil and may be found in different stages of decomposition. The decomposition is accomplished by the microorganisms[1] in the soil. As fresh residues are added, the numbers of microorganisms increase. As the amount of organic matter decreases, these organisms die, adding their remains to the mass of material in the soil. The end product of decomposition is humus. Humus is the most important form of organic matter in the soil and the form that has the greatest influence upon soil properties. It is usually dark brown to black and very small–less than .002 mm (2 microns). Humus is resistant to further decomposition; however, it will decompose slowly when soils are cultivated. All forms of organic matter are found in varying proportions in the soil at any given time, especially here in Hawaii where there is a year-round growing season which results in the continual addition of raw residues and activity of microorganisms.

Effects of Organic Matter in the Soil

Organic matter furnishes a source of energy for the microorganisms of the soil. The decomposition processes release carbon dioxide (CO_2) which combines with the soil solution to make the soil more acid. This increases the requirement for ground coral or coral sand to maintain the soil at a desirable pH level for plant growth. This decomposition breaks down the complex compounds of nitrogen, phosphorus, sulfur and other plant nutrients, mineralizing them to forms that plants use. However, all of these nutrients are not released for plant use until the microorganisms die. This decomposition process also increases the availability of plant nutrients already held in the soil.

[1]The microorganisms are bacteria, fungi, actinomycetes, protozoa, etc.

The physical condition of the soil is improved as sticky gluelike materials, produced by decomposition, serve as cementing agents to hold the mineral particles together in aggregates. In addition, the organic particles will combine with the mineral matter to form aggregates. This stabilizes them so that they do not break down easily when water is added or when the soil is mechanically manipulated. Many of the soils of Hawaii have very stable aggregates so that added organic matter has little or no affect upon them. Others are greatly improved by the incorporation of organic residues. To be effective, large quantities of organic matter are required. Applications of 10 to 15 tons of cow manure or its equivalent applied annually are required for satisfactory results in improving and maintaining the physical condition of most soils.

One result of improving the physical condition of soils by stabilizing its structure is the improvement of aeration of the soil. This allows more rapid adjustment of the air-water ratio in the soil and a better proportion of these in the pore space. Here, again, many soils of Hawaii will not be greatly improved as they have very stable structure and aeration if the soil is good. However, the addition of organic matter will be beneficial in other ways.

The exchange capacity of the soil is increased by the organic matter of the soil. The ability to take up and give off (exchange) many plant nutrient prevents the loss of the nutrients by leaching and retains them in available forms for plant use. The exchange capacity of organic matter accounts for its ability to combine with mineral material in the soil. This property is one of the most important features of soil organic matter, as it has great influence upon soil fertility.

The moisture-holding capacity of the soil is increased by increasing the organic content. The organic particles have the ability to absorb and hold water like a sponge; some of this water is available for plant use. This property, plus the effect upon physical properties, improves the tilth of the soil so that it can be managed properly for good plant growth.

In the sandy soils of Hawaii, the organic matter is especially important, as it is the primary source of exchange capacity and water-holding capacity in these soils.

Organic matter usually makes the soil darker colored. Since most of the organic matter is found in the surface of the soil, this portion of the soil is the darkest. In many of our Hawaii soils, the presence of iron and aluminum compounds gives the soil red or yellow colors even though the organic content of these soils are relatively high as compared to many temperate region soils. The darkest colored mineral soil in Hawaii—the Lualualei—has one of the lowest amounts of organic matter of any of the Hawaii soils. The dark color is due to the dispersed nature of the organic matter that coats the mineral particles and causes the dark color of the organic material to predominate.

Organic matter of the soil serves as a storehouse for many plant nutrients. Most of the nitrogen (95 to 96 percent) in the soil is in the organic fraction; 15 to 80 percent of the phosphorus, about 80 percent of the sulfur and large reserves of

boron and molybdenum are also found in the organic matter. These nutrients become available as the organic fraction decomposes. This is a slow process, so this source of nutrients cannot be depended upon as the only source of nutrients. Fertilizers must be used to meet the needs for satisfactory crop growth and yields.

Organic matter has a chelating[2] effect in the soil. Chelation prevents the available phosphorus, iron, zinc, copper and manganese from becoming "fixed" by chemical or physical means in the soil. Chelation also removes these plant nutrients from fixed forms and increases their availability for plant use.

Means of Adding Organic Matter to Soils

There are many methods of adding organic matter to soil. Some of these are: (1) green manure and cover crops, (2) crop residues, (3) animal manures and sewage sludge, (4) composts and (5) mulches.

Green manure crops (Fig. 1) are those grown for the specific purpose of returning organic residues to the soil. They are generally turned under while still green but just before the mature stage. At this stage the plant material contains the greatest amount of nitrogen and other plant nutrients, the maximum amount of moisture and the minimum amount of hard-to-decompose organic constitutents. However, green manure crops may also be turned under in the mature dry stage. They do not decompose in the soil as rapidly as the green moist materials, due to higher carbon-nitrogen ratio and lower moisture content. The legumes are excellent for use as green manure crops. Legume-grass mixtures are also excellent. Grasses alone are less satisfactory but still good sources of organic material for decomposition in the soil. When grasses or other nonlegumes are used, an extra source of nitrogen, incorporated at the same time, will hasten decomposition and prevent nitrogen deficiency on crops planted after the material has been turned under. Cover crops are those planted for the specific purpose of protecting the soil from wind and water erosion. These are close-growing crops that return large amounts of organic material to the soil when turned under. When these crops are incorporated into the soil, they become, in effect, green manure crops, as they add organic matter. If nonlegumes are used, extra nitrogen will be beneficial.

Crop residues (Fig. 2) are the parts of the plant remaining after man has harvested the portion that he uses. These are an important source of organic residues, as no extra labor or time is required to obtain or grow the material. They may consist of roots, stems or leaves, and often amount to large quantities of material. Sheet composting refers to the method of adding extra organic residues to the soil to be turned under to decompose when the land is prepared. This is, in effect, the same as crop residues, except the material is obtained from some other source and supplies additional organic residues for the soil. When nonlegumes are used as crop residues, additional sources of nitrogen will prove beneficial.

[2]Chelation is derived from the Greek word for claw. It is caused by a group of complex organic compounds that have high affinity for certain plant nutrients.

Fig. 1 Green manure and cover crops are excellent sources for adding organic materials to the soil. Legumes, such as the *Crotolaria junca* shown here, add nitrogen for crop use as well as organic matter to the soil.

Fig. 2 Crop residues are probably the most important means of returning organic matter to soils. Many crops, such as pineapple, return large quantities of residues to the soil.

Animal manures consists of the solid and liquid excreta of animals (Table 1.). Where numerous animals are run on pasture, large quantities of these materials will be added to the soil. Where animals are penned for fattening, milking, etc., large quantities of manures and bedding accumulate. Disposal of these solid wastes is a problem. In many areas, operators of feedlots, dairies, chicken farms, etc. will give away all the manure that can be used. Most manures are full of weed seeds and should be treated to kill them before application of the material to the soil. Sewage sludge (Fig. 3) is the solid waste product from sewage treatment plants. Large quantities of this product are produced, and disposal is a major problem. It is of higher plant nutrient content than animal manure. There are two types: activated and digested. Digested, the type most commonly available from sewage treatment plants in Hawaii, is of lower quality, contains viable tomato seeds and large amounts of cigaret filters which do not decompose easily. It needs shredding before use, to make a product that can be uniformly mixed into the soil. The activated product is higher in plant nutrients, has no tomato seeds and no cigaret filters or other impurities of that type. It is also more expensive. The activated sludge is produced by aeration and the addition of bacteria that produce a granular, higher nutrient content product. It is often sold as a fertilizer material where slow-release nitrogen is desired. All manures and sewage sludges are a potential source of flies and offensive odors, especially if not thoroughly mixed with the soil and when moist. However, careful and proper handling minimizes these disadvantages. These decompose rapidly in the soil and release their nutrients for plant use. They require no additional nitrogen as their carbon-nitrogen ratio is low.

Composts (Fig. 4) are waste organic residues that are partially decomposed or "predigested" before addition to the soil.[3] They may be made from almost any type of organic residue and, when properly made, are remarkably uniform in composition, being comparable to barnyard manure (cow) when ready for use. The composting process requires a great deal of labor, large quantities of wastes and a certain amount of time. It is generally more suitable for the home gardener or small operator than for large operations. However, it is an excellent source of organic material for the soil and a good method of disposing of waste and removing unsightly trash from around the home and garden.

Mulching (Fig. 5) is the use of organic residues on the surface of the soil to reduce water losses by runoff and evaporation, conserve plant nutrients, reduce weed infestations and control soil temperature. Mulches may consist of raw organic residues or materials that have been composted. It is not a means of adding organic matter to the soil unless it is mixed with the soil after having served its purpose as a mulch. Some decomposition of the material in contact with the soil surface occurs and accumulates. Where the soil is sufficiently porous, a small amount of the material may move into the soil by gravity.

[3]For additional information on composts see "Composts for Hawaii," Hawaii Cooperative Extension Service Circular 471.

Table 1 - Amount and Characteristics of Fresh Manure Produced by Some Animals in Hawaii[1]

Animal	Amt. produced[2] tons/yr/1000 lbs wt	Water content %	Total minerals lbs/ton	Total organic matter lbs/ton	N	P	K
					lbs/ton		
Chicken	4.8	54	332	588	34	10	10
Dairy cattle	13.5	79	38	322	10	2	10
Fattening cattle	7.5	80	45	395	15	4	9
Hog	15.3	75	161	399	10	3	8
Horse	9.0	60	149	386	14	2	12

[1]Data taken from various sources. These are average figures.
[2]Total excreta, including liquid and solid portions.

(A)

(B)

Fig. 3 Animal manures and sewage sludge are easily decomposable sources of organic matter for the soil. Sewage sludge (A) is higher in plant nutrients than are animal manures (B).

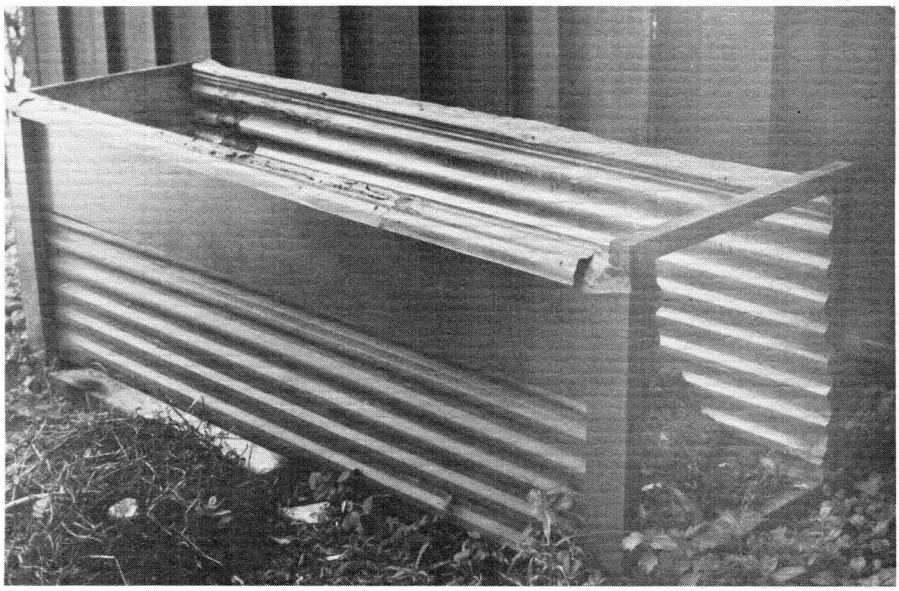

Fig. 4 Composts are an excellent way of disposing of waste organic materials around the home. Composts may be made from almost any plant or animal waste.

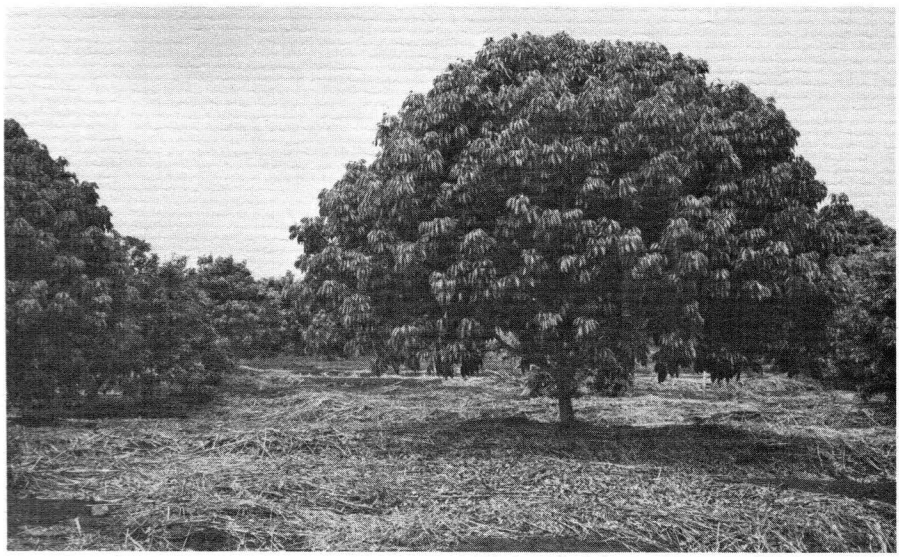

Photo courtesy of Dr. Y. Kanehiro, Dept. of Agronomy & Soil Science, U. of H.

Fig. 5 Organic mulches add organic matter to the soil when they are turned under. Little or no organic matter is added as long as the mulch remains on the surface of the soil. Nonorganic mulches, such as plastic, have no value in adding organic matter to soils.

Carbon-Nitrogen Ratio

The carbon-nitrogen (C:N) ratio of organic residues has been mentioned several times. This is an important factor, as it determines the rate of decomposition of the material, the available nitrogen and the total amount of material that may accumulate. Soil organic matter has a range between 8:1 and 20:1, the average being between 10 and 12 to 1. There is little variation in this ratio in the soils of Hawaii found in the same climatic conditions. However, there is great variation in the ratio in organic materials that may be added to the soil to supply organic matter (Table 2).

The time that available nitrogen is depressed may be long or short, depending on moisture, aeration and temperature of the soil. The rate of decay will be longer or shorter, depending upon the C:N ratio. The greater the amount of residues added, the longer the nitrogen supply will be depressed. The narrower the C:N ratio, the more rapidly decomposition will be accomplished. The younger and more succulent the material, the lower the C:N ratio. This is one reason that green manures are more effective when turned under green.

Since the C:N ratio of soil organic matter is reduced to a more or less constant ratio, the amount of soil nitrogen determines the amount of organic carbon that will be present where this ratio becomes constant. So the greater the amount of nitrogen in the original tissue, the greater will be the amount of soil organic matter that will result from its decomposition. This is one reason additional nitrogen is beneficial when added with the nonlegume residues. It increases the amount of organic matter (humus) that may accumulate and also supplies plant needs during the depression of available nitrogen in the soil.

Table 2 - The Characteristics of Some Common Organic Residues*

Material	C:N ratio**	Material	C:N ratio**
Alfalfa	13:1	Pineapple trash	55:1
Compost	15:1	Sawdust	500:1
Crotolaria - green	16:1	Straw	80:1
Crotolaria - mature	30:1	Sugarcane trash	50:1
Garbage	25:1	Weeds	80:1
Grass - green	40:1	Wood chips	400:1
Grass - mature	75:1		

*Data collected from various sources.

**Average data. Obviously the ratio of materials such as wood chips varies according to the type of plant from which derived. If the C:N ratio is less than 17:1, nitrogen will be immediately released for plant use when decomposition begins; if between 17:1 and 33:1, no nitrogen is released or needed; if higher than 33:1, additional nitrogen is needed for decomposition to prevent N deficiency of higher plants.

Table 3 - Organic Matter Content of Some Soils of Hawaii[1]

Soil Name	Great Soil Group[2]	Great Soil Group[3]	Rainfall (inches)	Organic Content %
Kawaihae	Red Desert	Camborthid	10	1.05
Lualualei	Dark Magnesium Clay	Chromustert	18	1.51
Waikaloa	Reddish Brown	Eutrandept	20	10.59
Honouliuli	Gray Hydromorphic	Chromustert	26	2.27
Molokai	Low Humic Latosol	Torrox	28	2.94
Kolekole	Humic Ferruginous Latosol	Humitropept	30	7.02
Waimea	Reddish Prairie	Eutrandept	30	14.97
Kaiwaihapai	Alluvial	Haplustoll	30	1.88
Kaneohe	Humic Latosol	Tropohumult	70	5.59
Maile	Latosolic Brown Forest	Dystrandept	72	19.45
Kona	Lithosol	Tropofolist	90	53.17
Jaucuas	Regosol	Ustipsamment	20	2.00
Hilo	Hydrol Humic Latosol	Hydrandept	140	15.80
Akaka	Hydrol Humic Latosol	Hydrandept	210	16.24

[1]Organic matter (% organic carbon x 1.724) in surface 10 inches of soil.
[2]1938 Soil Classification System.
[3]Soil Taxonomy System.

The total organic matter content of the soil depends upon temperature, rate and distribution of rainfall, texture of the mineral portion of the soil, minerals present in the soil and the drainage of the soil. Where any of these conditions change, as when soils are cultivated, the organic content changes. Careful soil management, including returning organic residues to the soil, will help maintain soil organic matter at the optimum level in the soil. Table 3 shows the organic matter content of some soils of Hawaii and indicates its relationship to climate.

Organic matter may cause some harmful effects if used improperly. Depression of available nitrogen, causing nitrogen deficiency of crop plants, is the most common harmful effect. However, too much organic residue at the time may cause the soil to be droughty or overaerated due to the too great bulk of material present. The decomposition of some materials may produce toxic substances in the soil. However, by maintaining the proper soil conditions, toxic materials disappear rapidly. Good drainage, tillage, lime and fertilizers reduce the probability of harmful effects from added organic matter.

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